Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 3 (2012) 364 – 369

www.elsevier.com/locate/procedia

45th CIRP Conference on Manufacturing Systems 2012

Evaluating Changeability Corridors for Sustainable Business Resilience

T. Bauernhansl[a], J. Mandel[a,]*, S. Diermann[a]

[a]*Fraunhofer Institute for Manufacturing Engineering and Automation, Nobelstraße 12, 70569 Stuttgart, Germany*

* Corresponding author. Tel.: +49-711-970-1980; fax:+49-711-970-1002.*E-mail address*: joerg.mandel@ipa.fraunhofer.de

Abstract

Most enterprises have not been able to establish a changeable factory or rather a changeable company yet. One of the main reasons for this is the absence of suitable systems to evaluate the economic sustainability of changeability in companies. This paper wants to lead the way and provide assistance to value changeability by presenting changeability types and a Sustainable Business Resilience Model based on proven financial instruments, which will be assigned in a novel way to the strategic enterprise level. Within the Sustainable Business Resilience Model, the understanding of financial instruments based on risk hedging needs to be modified to include a consideration of opportunities.

Keywords: Changeability, Changeability Types, Sustainable Business Resilience Model

1. Introduction

The traditional competitive advantages of European manufacturing companies, such as quality, a high level of reliability, and innovative technologies are no longer drivers of sustainable business success on globalized and ever volatile markets. Other economic regions catch up, being able to boast lower labor costs and higher labor productivity [1],[4]. But the trend towards more and more volatile and unpredictable demand fluctuations [3] also opens up new opportunities to differentiate from competitors [1], [2], [3], [6].

Previous flexibility approaches prove to be insufficient today: they focus too much on individual operations, on machines and their technical and logistical periphery, and on their integration into the information processing environment. Flexible manufacturing was directed at small and medium quantities and maximizing technical application and extending the period of use. It was all about technological developments. Future competitive opportunities, however, go together with a comprehensive structural changeability of the entire production system. This refers both to organization and technology and is mainly characterized and supported by advanced information and communication technology [13]. Well-prepared companies like this can adapt themselves very fast and efficiently beyond the limits of existing flexibility even when faced with turbulence such as fluctuations in quantity and order mix [1], [6].

Flexibility is understood as a production system's ability to adapt to a changing framework. This can be achieved by a pre-defined, planned set of measures for adapting to changes within a defined area. The provision of excessive flexibility should always be critically examined from a business point of view. If production is meant to be economically viable, companies cannot provide infinite flexibility. However, the planned flexibility would be insufficient if the capacity available for a certain production volume is too low to manage a market-driven change in quantity demand [5], [7].

Changeability, by contrast, is understood as the potential for implementing, when needed, organizational and technical changes by using the provided corridors of flexibility [5], [7]. So, the maximum flexibility corridor

doi:10.1016/j.procir.2012.07.063

must be clearly distinguished from the cost-effective changeability corridor. The objective is to determine a changeability corridor, which provides sufficient scope for different, varying flexibility corridors [Figure 1].

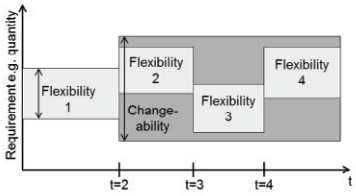

Fig. 1. Flexibility vs. changeability

To adapt organizational and technical structures, i.e. to shift flexibility corridors, is usually a matter of business planning. Trends in the operating profit, forecasts, as well as internal and external developments that were made use of, motivate managers to take actions, for instance to invest in new production capacity or to shut them down, or to kick off projects for organizational adaptations. In the face of increasingly unforeseeable, drastic changes in order situation and order mix, the right strategy is to continuously plan changeability steps (in situ-planning). It must also cover projections or forecasts including medium- and long-term operational goals [13].

Different kinds of costs need to be considered when creating and economically evaluating changeability. Apart from the time required to implement changeability, costs arise from enabling changeability, such as capital investment, and, most of all, from adapting the organizational structure.

Reliable forecasts, assumptions, and strategic decisions are prerequisite for economically viable changeability corridors. This is the only way to determine the costs for the creation of changeability corridors and for a faster repositioning of flexibility corridors within the changeability corridor.

At the same time, the benefit from enabling changeability needs to be quantified. This benefit is based on the concept of resilience. In academia, some scholars trace the concept of resilience to the child behavior literature where it is used to describe a child who is positive, focused, flexible and proactive, despite exposure to extremely challenging and stressful environments [11], [14]. Other scholars trace the notion of resilience to the field of materials science where it is used to describe the ability of a material to recover its original shape following a deformation [12] [15].Yossi Sheffi analyzes the high impact and low probability of disruptions and says that companies must at first identify the risk typologies and levels to create a resilient organization [12]. In the business environment and with a view to changeability, this understanding of resilience must be extended. So, resilience will be defined in the following as the ability of manufacturing companies to bring about positive business results in spite of a reduced ability to plan ahead, extremely volatile markets, and constant turbulence.

To evaluate the cost of changeability versus its benefit in the form of additional resilience, this paper draws on the analogy of future contracts. Similar to the manufacturing industry, the financial market forms a complex system of many different players, objects and mechanisms. The difficulty for both sectors is that future events cannot be reliably predicted. To hedge against unpredictable risks, the financial business uses, for example, conditional future contracts.

Accordingly, the costs for providing changeability corridors are identical with the premium paid by a manufacturing company to hedge against future events. The premium which has to be paid for this mainly takes the form of investments for highly flexible machinery and the qualification of the workforce. Apart from the premium for providing changeability, it is necessary to consider the running costs for maintaining the changeability corridor and for implemented changeability steps.

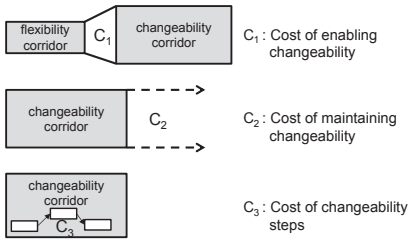

Fig. 2. Costs of changeability

The objective of the approach presented in the following is to help dimensioning the changeability corridors in manufacturing companies. In principle, it provides a mental framework for business decision-making on the road to changeability.

2. Option trading

A future contract is a financial term characterized by the time difference between conclusion and performance of a contract. Future contracts include purchase, exchange, forward transactions or option contracts and are distinguished from spot transactions. On the spot market, financial instruments are traded for delivery on a settlement date that lies two days forward. This is why all transactions with a different settlement date are called future contracts. Future contracts can be defined as contracts concluded today while the negotiated terms and conditions are fulfilled at an agreed date in the future [9]

Apart from the settlement date, future contracts can also be classified by the type of business transaction. Usually, a distinction is made between unconditional and conditional future contracts. Unconditional future

contracts are forward transactions, with buyer and seller entering into binding obligations. The buyer commits (long: obligation to buy) to purchase a specified underlying at a prearranged price and at an agreed future date, while the seller (short: obligation to sell) commits to deliver. It is also possible to exchange payment obligations instead of the underlying assets [10].

There are two stages of potential profits and losses in option trading. The first stage covers the conclusion of the option deal. This includes the sale or purchase of an option right and the payment of the option premium by the buyer. At the second stage, the option right is either exercised or it expires. The execution brings about the sale or purchase of the traded securities upon payment of the contractually agreed strike price [9].

In buying a call option, the buyer anticipates an increase of share prices (long call) and is given a theoretically unlimited profit potential, while the loss potential is calculated from the payment of the option premium. If the spot rate at the settlement date exceeds the value of the underlying, the buyer will exercise the option, but if it falls below the underlying, it makes no financial sense to exercise the option [9], [10]. The next figure illustrates this relationship.

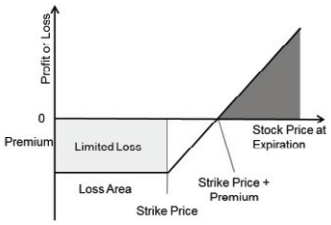

Fig. 3. Potential profit and loss in buying a call option [9]

3. Changeability types

To be able to compare different scenarios in this Business Resilience Model and allow for the positioning of potentially changeable companies, it first takes to define different changeability types. To this end, the conditional future contracts described above, which are well-known and tested in the financial business, are translated to the strategic enterprise level. To better understand the model, it is better to distance yourself from the original understanding of the financial instruments, which trace back to risk hedging. In terms of changeability, this kind of risk evaluation should be transformed into an evaluation of opportunities and capabilities.

If changeability is understood as the capability to shift, expand or reduce the flexibility corridor maintained in case of need, the sheer combination of these options provides nine ways to adapt the flexibility corridor. In the following, these adaptations are called ‘changeability types’. Since the topic is an increase of changeability, the focus is on the positive risk averse, constant risk averse, and positive conservative type of changeability (Figure 4). As in Figure 1, the x-axis shows the time t, while the y-axis represents the requirements, for instance quantity.

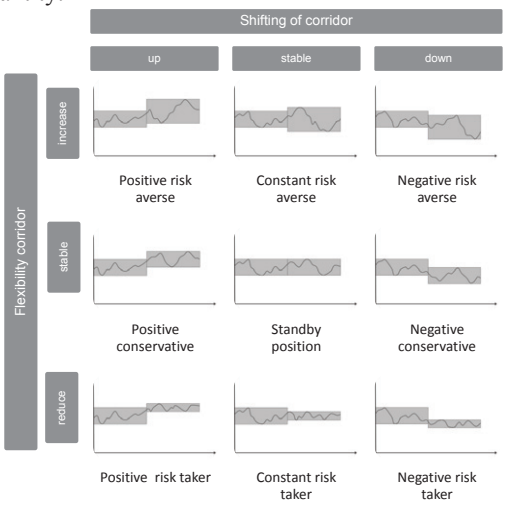

Fig. 4. Types of changeability

The changeability types most significant to this study topic will be looked at in detail. The variable ‘output in units’ will be assigned to the y-axis to facilitate understanding.

The positive risk averse type anticipates to sell more or less units in the future. Through his strategy, he wants to profit from an economic upturn or offset an economic downturn. The name of this changeability type implies that the positive risk averse hedges against uncertainties through a larger flexibility corridor. And in case of more volatile sales quantities, such a flexibility corridor, shifted upwards and expanded, could become necessary to come to terms with strongly fluctuating quantities.

The conservative risk averse will not shift the flexibility corridor. Instead, he will expand it both in positive and negative direction. Simply by expanding the corridor, the conservative risk averse obtains a certain safety buffer to profit both from a positive market development and to compensate for negative developments.

The last changeability type to be described is the standby position which is identical to the writer described before. The standby position does not change the existing flexibility corridor. Instead, he avoids any investment that could arise through changeability. At the same time, he cannot benefit from any positive market developments or offset negative market developments.

Another aspect to be considered in positioning changeable companies is the ‘period of change’. This term designates the necessary time it takes from the current state, in terms of the existing flexibility corridor, to the target state of changeability. Three ideal types can be derived: ad-hoc, rapid and slow changer. The ad-hoc changer can change within an unbelievably short time span, while the slow changer accomplishes the change very slowly only as a great deal of effort is involved.

The rapid changer can quickly adjust to change. The ad-hoc changer is an ideal type which probably does not exist in everyday business. In practice, the types are confined to rapid and slow changers. The changeability types described before are represented as ad-hoc changers. However, these changeability types can also be represented by other types of changers.

4. Evaluation models

Changeability would not be needed in industrial practice, if the maintained flexibility corridors were sufficiently large. Since such a corridor is very uneconomic and therefore mostly out of the question in practice, the idea is not further considered here. Instead, the concept of optimum changeability is promoted. Here, the balance for each company between maximum and optimum changeability must be found. To evaluate the optimum degree of changeability and the suitability of specific types of changeability, a cost-benefit model is introduced.

5. Cost model

The cost model presents a first approach to identify the optimum degree of changeability, while exclusively analyzing costs. The model illustrates the connection between changeability, investment costs of changeability, and the cost of change. The less changeable a company, the lower the investment costs. The latter are rising with increasing changeability. The cost curve of change takes the opposite direction. If a company is positioned as not changeable, the costs at the beginning of change are very high; for a changeable company, however, they are very low. Aggregating the cost of change and the investment cost of changeability will result in changeability-related total costs. The curve of changeability-related total costs is parabolic. At the lowest point of the curve, the optimum costs of changeability can be found.
The model is divided into five areas: The standby option covers companies that make no or little investment. The radical change area represents a different extreme, where companies invest a lot to achieve a maximum of changeability. Moreover, there is an area of cost-effective changeability, which lies near the optimum change. Insufficient change and excessive change are found below or above the area of cost-effective changeability and touch the extreme areas. Figure 5 shows the modified cost model.
The model is solely based on a cost analysis and does not consider any other benefits of changeable positioning. Thus, when viewed under cost aspects, a company might be in the area of optimum costs though it lies far outside the economic optimum. This is the case, for instance, if companies can manufacture at very low cost through suitable measures but cannot serve 80% of the market. Therefore, it is necessary to include other variables apart from costs in a model for evaluating changeability.
Apart from the mentioned points, the cost model should be able to verify if the changeability types are suitable to achieve the desired changeability.

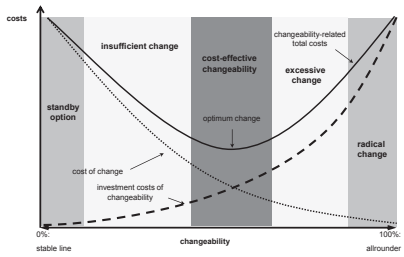

Fig. 5. Cost model of changeability

6. Sustainable business resilience model

The Sustainable Business Resilience Model serves as a starting point for evaluating the suitability of change enablers in the context of changeability. Change enablers are changeable methods, which increase the changeability of a company.
Change enablers are selected with a view to how much they enable the favored changeability type to achieve the appropriate degree of changeability. This means a change enabler ideally represents a specific type of changeability. Since it is not the purpose of this work to review countless change enablers, all change enablers are summarized under the corresponding type of changeability so that the Sustainable Business Resilience Model is explained on the ideal changeability types. The model makes it possible to verify if the change enabler or type actually achieves the benefit the company expects from its implementation.
The aim of combining the changeability types with the Sustainable Business Resilience Model is to provide a novel and practicable business tool for developing strategies in the field of changeability.
Before an investment in changeability is made, companies have to decide what basic changeability type is best suited for the current company situation. To improve the basis for decision-making, scenarios are used to compare different types of changeability. The Sustainable Business Resilience Model is presented by comparing the two changeability types of standby position and constant risk averse.
Based on the previous findings, the model to evaluate the changeability types regarding the required changeability is presented. The conditional future contracts described at the beginning provide the basis for this.
The changeability required by the market is represented on the x-axis, and on top of it a positive or negative development of the sustainable business resilience and

of the economic success is indicated on the y-axis. Positive resilience is understood as properly anticipated changeability, supporting the sustainable business continuity. Negative resilience, on the other hand, puts the sustainable business continuity at risk, since the required changeability potential was misinterpreted. The model does not show the development over time, but illustrates the static view of conditional future contracts.

On closer inspection, the standby position type is not a real changeability type, since the available flexibility corridor is maintained. It rather demonstrates what is to be expected in the future if the company does not invest in changeability but continues to work only with the given flexibility corridor and means [cf. Figure 5].

The »development of resilience« curve of the standby position differs very much in its shape from the other changeability types. If the required changeability remains within the maintained flexibility corridor, the resilience value of this changeability type is positive. But if the required changeability exceeds the existing flexibility corridor, the resilience value drops, like a unit step function, to the negative. Since maintaining flexibility is associated with costs, they affect the economic success. Analog to conditional future contracts, they can be regarded as a premium which the company pays to achieve a positive resilience value in a defined flexibility corridor. Thus, a local low at the normal level of required changeability is reached. If the required changeability drops out of the normal level, the economic success will reach its maximum at the boundaries of the flexibility corridor. After that, the economic success decreases and, similar to the sale of a short call, can take on a theoretically infinite negative value of economic success [cf. Figure 6].

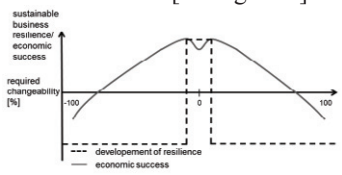

Fig. 6. Sustainable business resilience: standby position

By contrast, the constant risk averse changeability type achieves a changeable position by expanding the flexibility corridor both in negative and positive direction to achieve the required anticipated changeability. Accordingly, developments of the required changeability, shown as line in Figure 7, can be offset if they remain part of the changeable position of the company. If the required changeability drops out of this corridor, the framework of changeability available to the company is insufficient. The scenario in Figure 7 shows that a company can depart from the normal level (0%). The company changes according to the strategy of the constant risk averse and will be able in the future to master the increased required changeability from normal level. Figure 7 displays this scenario graphically.

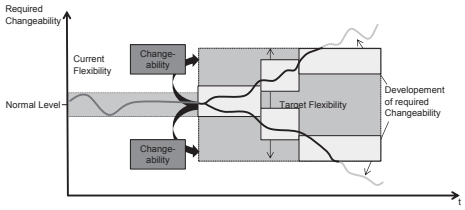

Fig. 7. Changeability type: Constant risk averse

Similar to the standby position, the “development of resilience” curve of the constant risk averse looks like a unit step function. Due to the investment in changeability, it is different in the higher resilience value which applies to the changeability corridor.

A higher resilience value requires a changeability corridor, necessitating both fixed and variable costs. The costs of change management also need to be added to the investment costs, as more communication and transparency become necessary. So, the increase in cost reduces the economic success of the company at the time of the investment (normal level ≙ 0% required changeability). This circumstance refers to the understanding of buying a call option. It results in a local low at normal level. With increasing and decreasing changeability, the latter develops positive right to the maximum, which is defined by the limits of the available changeability. If the required changeability oversteps the changeability corridor, the economic success decreases and can take on a theoretically infinite negative value.

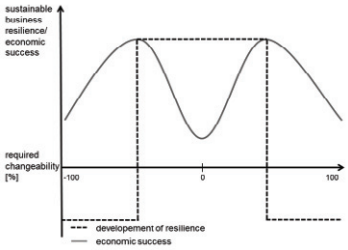

Fig. 8. Sustainable business resilience: Constant risk averse

After looking at the »development of resilience« and the economic success of standby position and constant risk averse, the two changeability types can be compared by the Sustainable Business Resilience Model. Figure 8 illustrates the comparison of the changeability types. What strikes the eye is the difference in the resilience value of the two changeability types. The difference in the established resilience value can be calculated from the difference of the integrals of the functions of the standby position and the constant risk averse. The difference of the integrals is defined for the standby position by the maintained flexibility and for the constant risk averse by the maintained changeability.

The constant risk averse pays for the increased resilience value by a low economic success value at normal level, taking the form of a premium. This enables him to

benefit from both a positive required changeability and in the negative field to master the required changeability. By contrast, the economic success value of the standby position is more positive. The higher economic success value remains valid only for the area between the interfaces of both curves [cf. shaded area].

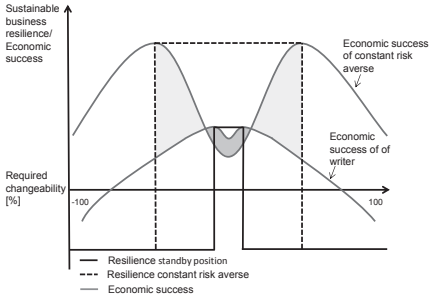

Fig. 9. Sustainable business resilience: comparison of changeability types

The fields outside the interfaces illustrate the more positive success of the constant risk averse [cf. hatched areas]. Accordingly, companies with changeable corporate positioning can both achieve a positive resilience value and, from a certain degree of required changeability, achieve more positive economic results that would not be possible in the standby position.
The decision on which changeability strategy, in terms of changeability types, to apply mainly depends on the anticipation of changeability required in the future and the reliability of forecasting. Another aspect included in strategic decision-making is the willingness to invest and the capital intensity of the chosen changeability method.

7. Summary

In ever more dynamic and turbulent markets, an appropriate degree of changeability guarantees sustainable business continuity. A novel approach was presented to evaluate the appropriate degree of changeability, based on the changeability types, the cost model and the Sustainable Business Resilience Model, which basically draws on the conditional future contracts.
The changeability types cover all conceivable corporate positions in terms of changeability. In addition to the changeability types, three different types of changers were defined, with the aim of the required period of change being to approximate to the ideal type of the ad-hoc changer.
The first method presented to identify the optimum degree of changeability exclusively focused on costs and was based on the cost model. The intrinsic weaknesses of the cost model led to the development of the Sustainable Business Resilience Model. This is the first model that makes it possible to validate the suitability of changeability types with regard to the optimum degree of changeability. Scenarios were used to compare different changeability types, while the model itself indicates the development of sustainable business resilience and economic success. Positive resilience is understood as properly anticipated changeability, supporting sustainable business continuity. Negative resilience, by contrast, endangers sustainable business continuity, since the required potential for changeability was misinterpreted. In an illustrative application of the model, the changeability types of the standby position and of the constant risk averse were compared. The decision on which changeability strategy to apply, in terms of changeability types, mainly depends on the anticipation of changeability required in the future and the reliability of forecasting. Another aspect included in strategic decision-making is the willingness to invest and the capital intensity of the chosen changeability method.

References

[1] Spath, D., Hirsch-Kreinsen, H., Klinkel, S., 2008, Organisatorische Wandlungsfähigkeit produzierender Unternehmen: Unternehmens-erfahrungen, Forschungs- und Transferbedarfe, Fraunhofer IRB Verl.
[2] Berkholz, D., 2008, Einleitung, Wandlungsfähige Produktionssysteme - der Zukunft einen Schritt voraus, in: NYHUIS, Peter (Hrsg.), Wandlungsfähige Produktionssysteme: Heute die Industrie von morgen gestalten, Garbsen, 13–18
[3] Nyhuis, P. (Hrsg.), 2008, Wandlungsfähige Produktionssysteme: Heute die Industrie von morgen gestalten, Garbsen
[4] Wiendahl, H.-H., 2010, Sozio-technisches Auftrags-management: Grundlagen, Konfiguration, Einführung, Springer
[5] Heinen, T., Rimpau, C., Wörn, A., 2008, Wandlungsfähigkeit als Ziel der Produktionssystem-gestaltung, in: Nyhuis, P. (Hrsg.), Wandlungsfähige Produktionssysteme: Heute die Industrie von morgen gestalten, Garbsen, 19–32
[6] Wildemann, H., Zäh, M. F., Müller, N., Krauß, U., Loth, M., 2005, Wandlungsfähige Auftrags-abwicklung als Voraussetzung für effizientes Produzieren in Netzwerken, in: Ferstl, O. K., 2005, Wirtschaftsinformatik Proceedings, 2005, in: Ferstl, O. K.; Sinz, E. J.; Eckert, S.; Isselhorst; T. (Hrsg.), 2005, Wirtschaftsinformatik 2005: eEconomy, eGovernment, eSociety. 7. Internationale Tagung Wirtschaftsinformatik 2005, Physica-Verlag
[7] Zäh, M., Möller, N., Vogl, W., 2005, Symbiosis of Changeable and Virtual Production – The Emperor's New Clothes or Key Factor for Future Success?, in: Zäh, Michael (Hrsg.), 1st International Conference on Changeable, Agile, Reconfigurable and Virtual Production, Utz
[8] Cisek, R., Habicht, C., Neise, Patrick, 2002, Gestaltung wandlungsfähiger Produktionssysteme, 97 No. 9, 441–445
[9] Perridon, L., Steiner, M., Rathgeber, A. W., 2009, Finanzwirtschaft der Unternehmung. 15., überarb. und erw. Auflage, Vahlen
[10] Breidthardt, J., 2008, Die Behandlung ausgewählter derivativer Finanzinstrumente und mezzaniner Finanzierungsformen nach HGB, im Steuerrecht und nach IFRS. CT Salzwasser-Verl
[11] Wustmann, C., 2004, Resilienz: Widerstands-fähigkeit von Kindern in Tageseinrichtungen fördern Beiträge zur Bildungsqualität, Beltz, 18
[12] Sheffi, Y., 2005, The Resilient Enterprise -Overcoming 3ulnerability for Competitive Advantage, MIT Press
[14] Westkämper, E., Zahn, E., 2009, Wandlungsfähige Produktionsunternehmen - Das Stuttgarter Unter-nehmensmodell, Springer, 13